NACA

RESEARCH MEMORANDUM

WIND-TUNNEL INVESTIGATION AT LOW SPEED OF THE EFFECTS OF SYMMETRICAL DEFLECTION OF HALF-DELTA TIP CONTROLS ON THE DAMPING IN ROLL AND YAWING MOMENT DUE TO ROLLING OF A TRIANGULAR-WING MODEL

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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WIND-TUNNEL INVESTIGATION AT LOW SPEED OF THE EFFECTS OF SYMMETRICAL DEFLECTION OF HALF-DELTA TIP CONTROLS ON THE DAMPING IN ROLL AND YAWING MOMENT DUE TO ROLLING OF A TRIANGULAR-WING MODEL

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SUMMARY

A low-speed investigation was made in the Langley stability tunnel to determine the effects of symmetrical deflection of half-delta tip controls on the damping in roll and yawing moment due to rolling of a triangular-wing model.

The results showed that a negative deflection of the tip controls caused an increase in the damping in roll over the lift-coefficient range from about 0.1 to 0.6 but generally resulted in a slight decrease beyond these limits for the deflection range investigated.

A negative deflection of the tip controls caused a negative increment in the yawing moment due to rolling which was only roughly proportional to control deflection and varied erratically with lift coefficient.

For a control deflection of -20°, increasing the control size caused a small negative increment in the yawing moment due to rolling throughout the lift range and decreased the damping in roll slightly for lift coefficients above about 0.8 for the range of control sizes investigated.

INTRODUCTION

Wings of triangular plan form, combining the structural advantages of low aspect ratio and high taper with the aerodynamic benefits of a highly swept leading edge, have been shown to be suitable for flight up to moderate supersonic speeds. The problem of obtaining adequate longitudinal and lateral control with acceptable control forces is rather difficult, however. Conventional hinged flaps, such as those used in the investigations reported in references 1 and 2, appear ~~to~~ be reasonably effective, although the hinge moments are of such magnitude that a powerful boost system probably would be required in order to operate the controls. The use of half-delta tip controls, pivoted near their optimum centers of pressure, would seem to offer one means of reducing the hinge moments within acceptable limits. Results of unpublished tests of such controls have indicated, however, that in order ~~to~~ obtain sufficient lateral-control effectiveness at high angles of attack the controls may have to be deflected differentially from an initial negative (nose-down) deflection. The initial negative deflection of the controls probably results in a reduced tendency toward tip stalling at high angles of attack, which, in addition to improving the lateral control effectiveness, might be expected to have some effect on the stability derivatives resulting from rolling.

The present investigation, therefore, was made to determine experimentally the effects of initial control deflections on the damping in roll and on the derivative of yawing moment due to rolling.

SYMBOLS

The data presented herein are in the form of standard NACA coefficients of forces and moments which are referred to the stability system of axes with the origin at the quarter-chord point of the mean aerodynamic chord. The positive direction of forces, moments, and angular displacements are shown in figure 1. The coefficients and symbols are defined as follows:

C_L lift coefficient (L/qS)

C_l rolling-moment coefficient (L'/qSb)

C_n yawing-moment coefficient (N/qSb)

L lift, pounds

L' rolling moment, foot-pounds

N yawing moment, foot-pounds

A aspect ratio, 2.31 (b^2/S)

b wing span, 3.04 feet

S wing area, 4.00 square feet

S_c control area (total), square feet

c wing chord parallel to plane of symmetry, feet

$\bar{c}$ wing mean aerodynamic chord, 1.76 feet $\left(\frac{2}{S}\int_0^{b/2} c^2dy\right)$

q dynamic pressure, pounds per square foot $(\rho V^2/2)$

ρ mass density of air, slugs per cubic foot

V free-stream velocity, feet per second

α angle of attack measured in plane of symmetry, degrees

δ symmetrical deflection of both control surfaces, degrees

p rolling angular velocity, radians per second

$pb/2V$ wing-tip helix angle, radians

$$C_{n_p} = \frac{\partial C_n}{\partial \frac{pb}{2V}}$$

$$C_{l_p} = \frac{\partial C_l}{\partial \frac{pb}{2V}}$$

APPARATUS, MODEL, AND TESTS

The tests of the present investigation were made in the 6- by 6-foot test section of the Langley stability tunnel. The lift characteristics of the model were obtained with the model mounted on a single strut support which was in turn connected to a conventional six-component balance system. The aerodynamic characteristics of the model in roll were obtained with the model mounted on the forced rotation rig described in reference 3. The rolling moment and yawing moment of the model when mounted on the forced-rotation rig were measured by means of strain gages.

All the tests were made with the model mounted at the quarter-chord point of the wing mean aerodynamic chord. The gap between the model and the mounting point was closed by a small canopy to prevent air flow through the gap.

The model used in this investigation was a triangular wing (fig. 2) constructed of laminated mahogany. The wing had a 60° sweptback leading edge, an aspect ratio of 2.31, and a basic NACA $65_{(06)}$-006.5 airfoil section parallel to the plane of symmetry, modified to have straight sides from the trailing edge to the point of tangency with the 70-percent-chord point. The wing was provided with half-delta tip controls whose total area was 0.05, 0.10, or 0.15 of the wing area.

The following table summarizes the tests made, the range of variables, and the quantities measured during the investigation.

S_c/S	δ (deg)	α (deg)	pb/2V (radians)	Quantities measured
0.10	0, -20, -30	-4 to 37	0	L
0.05, 0.10, 0.15	-20	-4 to 37	0	L
0.10	0, -20, -30	0 to 37	-0.08 to 0.08	N, L'
0.05, 0.10, 0.15	-20	0 to 37	-0.08 to 0.08	N, L'

All the tests were made at a dynamic pressure of 39.7 pounds per square foot, which corresponds to a Mach number of 0.17 and a Reynolds number of 2,060,000 based on the wing mean aerodynamic chord of 1.76 feet. A photograph of the model mounted on the forced-rotation rig in the Langley stability tunnel is presented as figure 3.

CORRECTIONS

Approximate jet-boundary corrections have been applied to the angle of attack and to the rolling-moment coefficient by the methods of references 4 and 5, respectively. No blocking or tare corrections have been applied to the data.

RESULTS AND DISCUSSION

Lift Characteristics

The measured lift characteristics of the model are shown in figure 4. The data of figure 4(a) show the variation of lift coefficient with angle of attack for various deflections of the control having $\frac{S_c}{S} = 0.10$, and the data of figure 4(b) show the variation of lift coefficient with angle of attack for various S_c/S ratios and a control deflection of -20°. These data show a change in lift approximately proportional to control deflection or to control area for a given deflection at low angles of attack. These data are presented herein primarily to relate the lift coefficient and angle of attack in order to facilitate the analysis of the rolling derivatives for the various model configurations.

Rolling Characteristics

The rolling parameters C_{n_p} and C_{l_p} of the various model configurations are presented in figures 5 and 6 as functions of the angle of attack and lift coefficient. The following discussion generally is limited to the variation of the parameters with lift coefficient, but the remarks are generally applicable also to the variation of the parameters with angle of attack.

Effect of control deflection.- The effects of control deflection were determined only for the configuration with $\frac{S_c}{S} = 0.10$, and the results are shown in figure 5. With the controls undeflected, negative values of C_{n_p} were obtained only for a small range of lift coefficients near $C_L = 0$ with positive values of C_{n_p} resulting for lift coefficients above about 0.24. The change from negative to positive values of C_{n_p} has been attributed to the increased profile drag, which results from partial separation of flow from the wing surfaces (see reference 6). A negative deflection of the controls contributed a negative increment to C_{n_p} throughout the lift-coefficient range and hence also extended the range of negative values of C_{n_p} to higher lift coefficients. The increment in C_{n_p} caused by control deflection was only roughly proportional to the control deflection and varied erratically with lift coefficient.

The measured value of C_{l_p} with controls undeflected was -0.165 at $C_L = 0$, which agrees well with the value of -0.158 given by the theory of reference 7. The damping in roll was nearly constant in the lift-coefficient range from $C_L = 0$ to about $C_L = 0.35$ but decreased with increasing lift coefficient for lift coefficients above about $C_L = 0.35$. The general character of the damping-in-roll curve through the lift range is similar to that shown in reference 8 for a triangular wing having 63.4° sweptback leading edges and flat-plate airfoil sections. However, since a higher maximum lift coefficient was obtained in the present tests - probably because of the higher Reynolds number and differences in airfoil section - the values of C_{l_p} at a given lift coefficient near maximum lift were found to be more negative than those of reference 8. The pressure-distribution investigations of references 9 and 10 have shown that at low and moderate angles of attack the section-lift-curve slopes of sections near the wing tips may be considerably higher than the average lift-curve slope of the wing. This phenomenon and the early tip stall associated with triangular wings probably account for the nonlinear variation of C_{l_p} with lift coefficient. The loss in C_{l_p} at high lift coefficients is caused by the stall progressing inboard from the wing tips. Deflecting the tip controls -20° caused a small increase in the damping in roll at moderate lift coefficients (near about $C_L = 0.25$) and a deflection of -30° caused a decrease in C_{l_p} near zero lift but an increase in C_{l_p} from $C_L = 0.1$ to about $C_L = 0.6$. A control deflection of either -20° or -30° generally decreased C_{l_p} for lift coefficients above about 0.6. The effects of tip-control deflection on the damping in roll probably can be associated with the variation of spanwise loading characteristics with angle of attack and the change in effective angle of attack of the tip due to control deflection. A delay in tip stall (by a reduction in the effective tip angle of attack) caused a delay in the reduction in C_{l_p} to higher angles of attack.

Effect of control size.- The effects of control size on the variation of C_{n_p} and C_{l_p} with angle of attack and lift coefficient are shown in figure 6 for the three control sizes investigated at a deflection of -20°. The data show a slight negative increment in C_{n_p} throughout the lift range caused by increasing control size. The damping-in-roll parameter C_{l_p} was only slightly affected by changes in control size at low and moderate lift coefficients but showed a small decrease in C_{l_p} with increasing control size for lift coefficients above about 0.8 for the range of control sizes investigated.

CONCLUSIONS

The results of an investigation to determine the effects of symmetrical deflection of half-delta tip controls on the rolling characteristics of a triangular-wing model have led to the following conclusions:

1. A negative deflection of the tip controls caused an increase in the damping in roll over the lift-coefficient range from about 0.1 to 0.6 but generally resulted in a slight decrease beyond these limits for the deflection range investigated.

2. A negative deflection of the tip controls caused a negative increment in the yawing moment due to roll which was only roughly proportional to control deflection and varied erratically with lift coefficient.

3. For a control deflection of -20°, increasing the control size caused a small negative increment in the yawing moment due to rolling throughout the lift range and decreased the damping in roll slightly for lift coefficients above about 0.8 for the range of control sizes investigated.

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REFERENCES

1. Stephenson, Jack D., and Ameudo, Arthur R.: Tests of a Triangular Wing of Aspect Ratio 2 in the Ames 12-Foot Pressure Wind Tunnel. II - The Effectiveness and Hinge Moments of a Constant-Chord Plain Flap. NACA RM A8E03, 1948.

2. Wolhart, Walter D., and Michael, William H., Jr.: Wind-Tunnel Investigation of the Low-Speed Longitudinal and Lateral Control Characteristics of a Triangular-Wing Model of Aspect Ratio 2.31 Having Constant-Chord Control Surfaces. NACA RM L50G17, 1950.

3. MacLachlan, Robert, and Letko, William: Correlation of Two Experimental Methods of Determining the Rolling Characteristics of Unswept Wings. NACA TN 1309, 1947.

4. Silverstein, Abe, and White, James A.: Wind-Tunnel Interference with Particular Reference to Off-Center Positions of the Wing and to the Downwash at the Tail. NACA Rep. 547, 1936.

5. Evans, J. M.: Stability Derivatives. Wind Tunnel Interference on the Lateral Derivatives l_p, l_r, and l_v with Particular Reference to l_p. Rep. ACA-33, Australian Council for Aeronautics, March 1947.

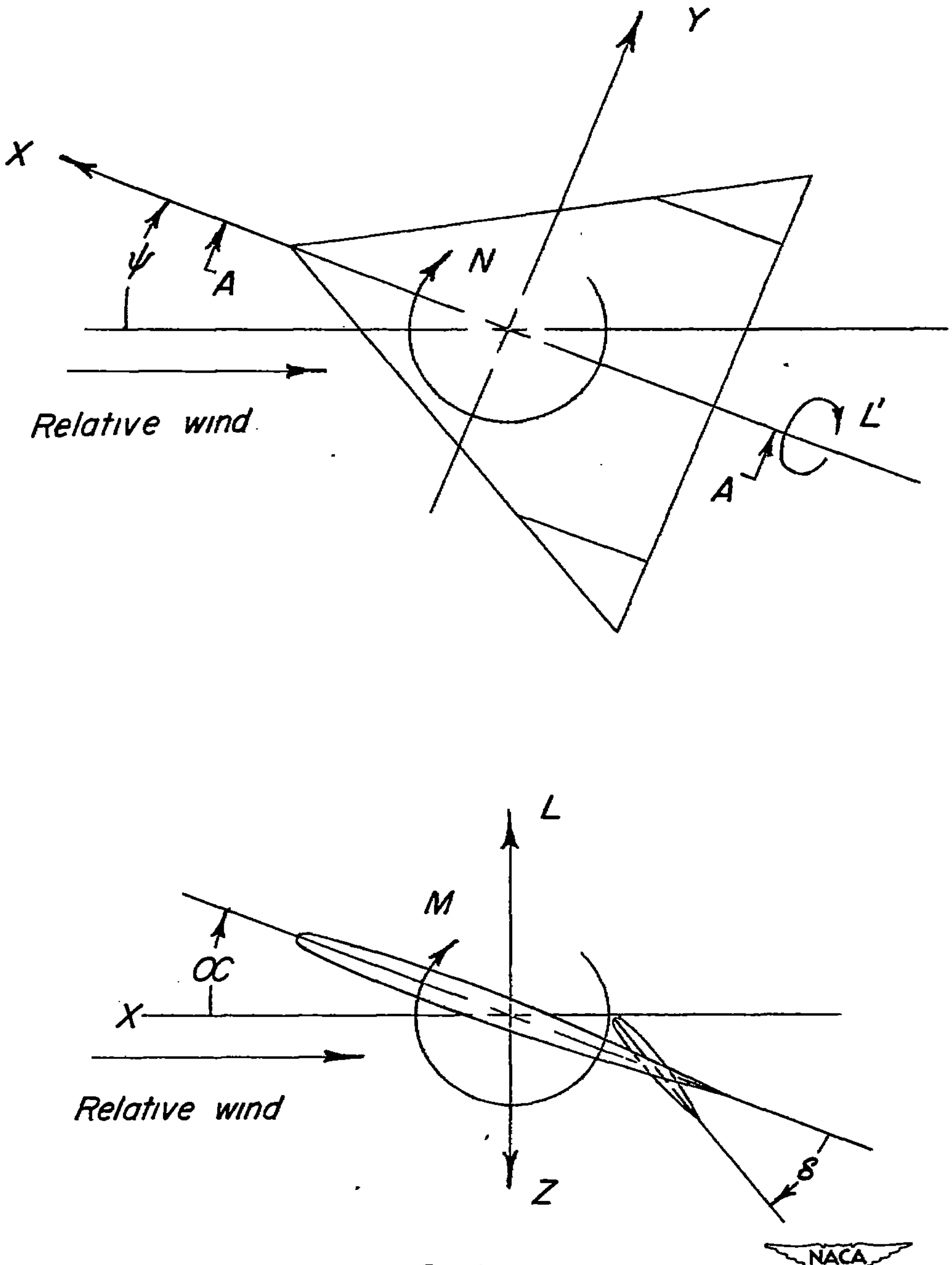
6. Goodman, Alex, and Fisher, Lewis R.: Investigation at Low Speeds of the Effect of Aspect Ratio and Sweep on Rolling Stability Derivatives of Untapered Wings. NACA Rep. 968, 1950.

7. Bird, John D.: Some Theoretical Low-Speed Span Loading Characteristics of Swept Wings in Roll and Sideslip. NACA Rep. 969, 1950.

8. Tosti, Louis P.: Low-Speed Static Stability and Damping-in-Roll Characteristics of Some Swept and Unswept Low-Aspect-Ratio Wings. NACA TN 1468, 1947.

9. Anderson, Adrien E.: Chordwise and Spanwise Loadings Measured at Low Speed on Large Triangular Wings. NACA RM A9B17, 1949.

10. Graham, David: Chordwise and Spanwise Loadings Measured at Low Speeds on a Large Triangular Wing Having an Aspect Ratio of 2 and a Thin, Subsonic-Type Airfoil Section. NACA RM A50A04a, 1950.



Section A-A

Figure 1.- System of axes used. Positive direction of forces, moments, and angular displacements is indicated.

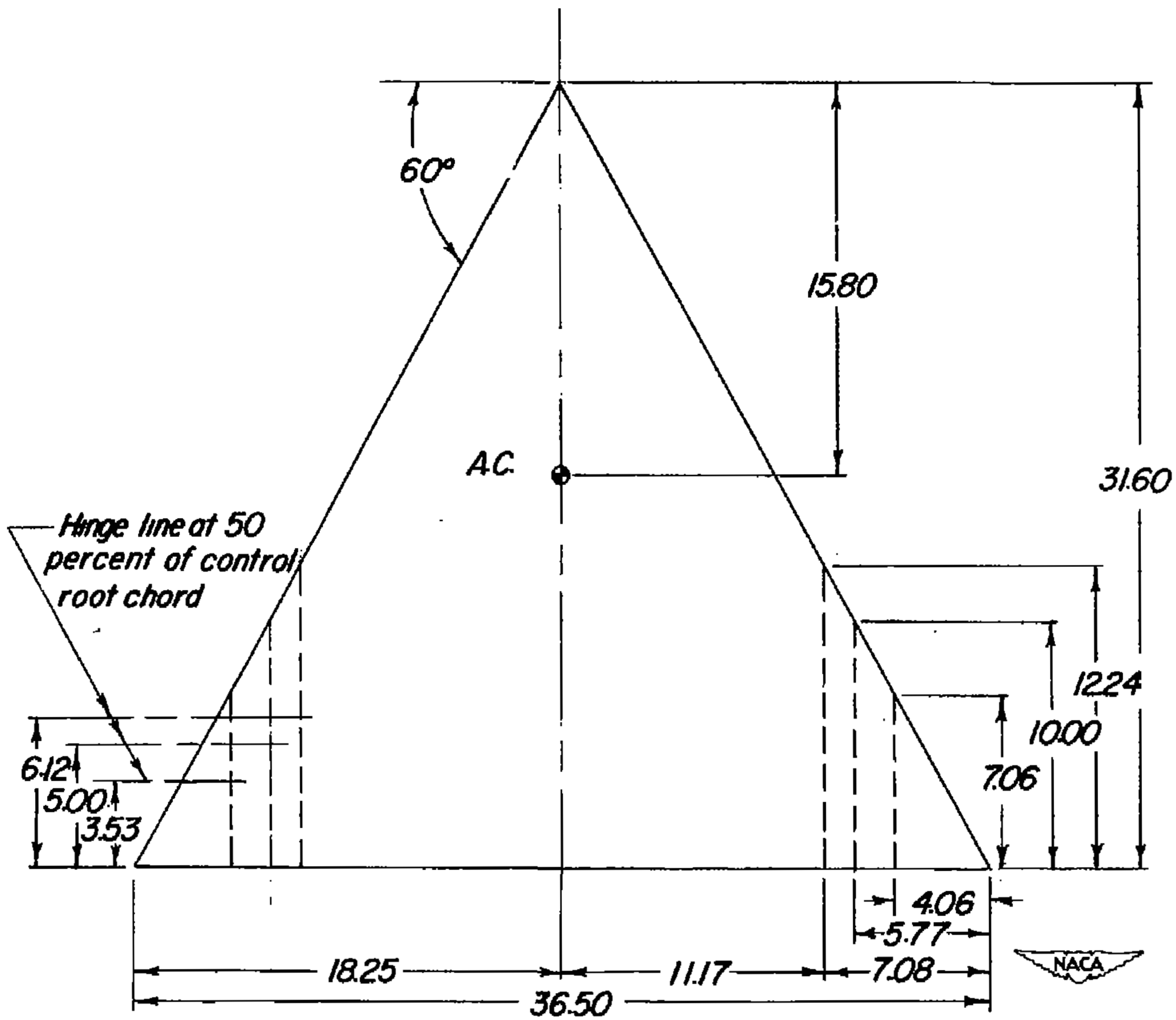
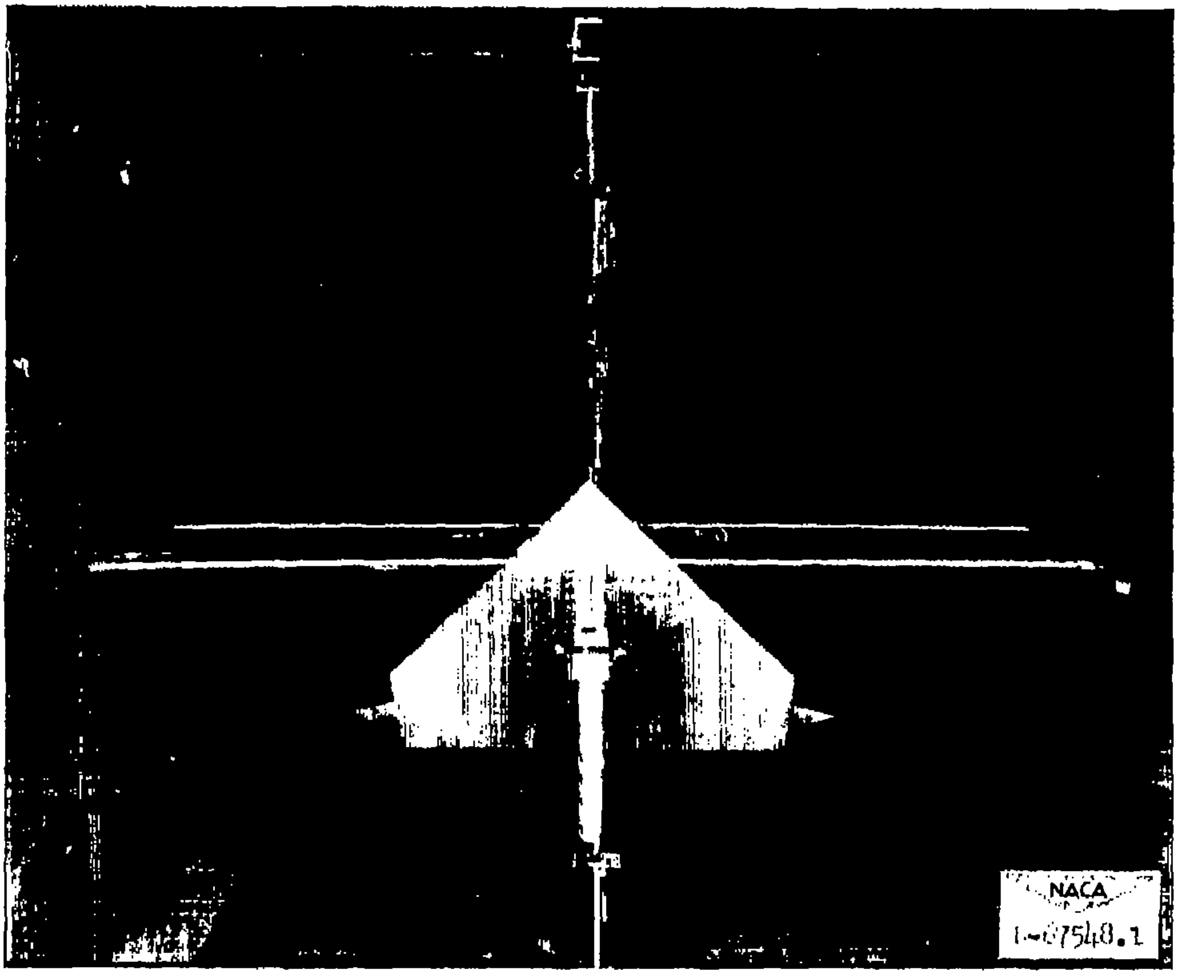
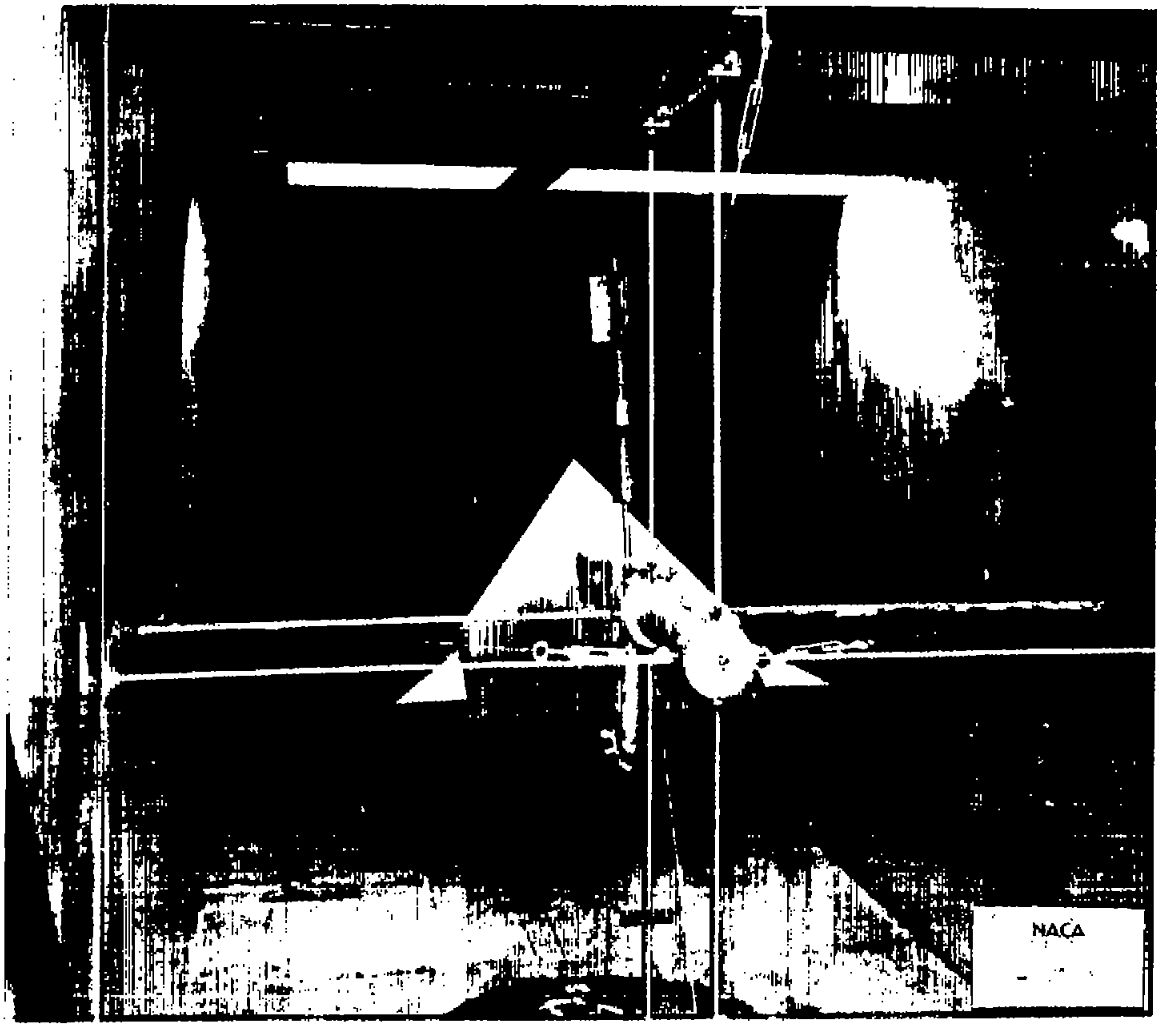


Figure 2.- Geometric characteristics of the wing and control configurations tested. (All dimensions in inches.)



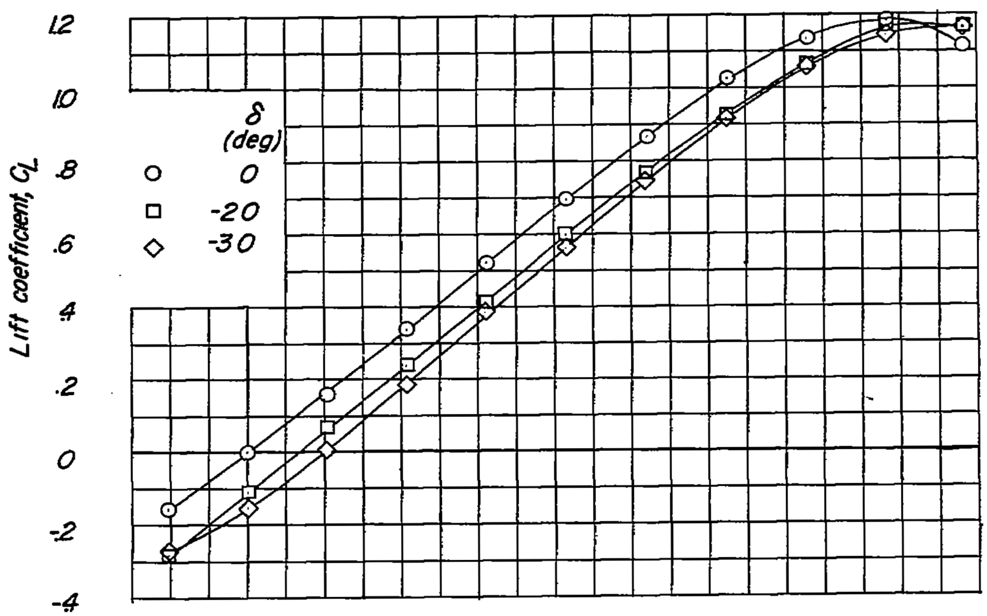
(a) Front view.

Figure 3.- Triangular wing with $\frac{S_c}{S} = 0.10$ controls deflected -20° mounted on the forced rotation rig.

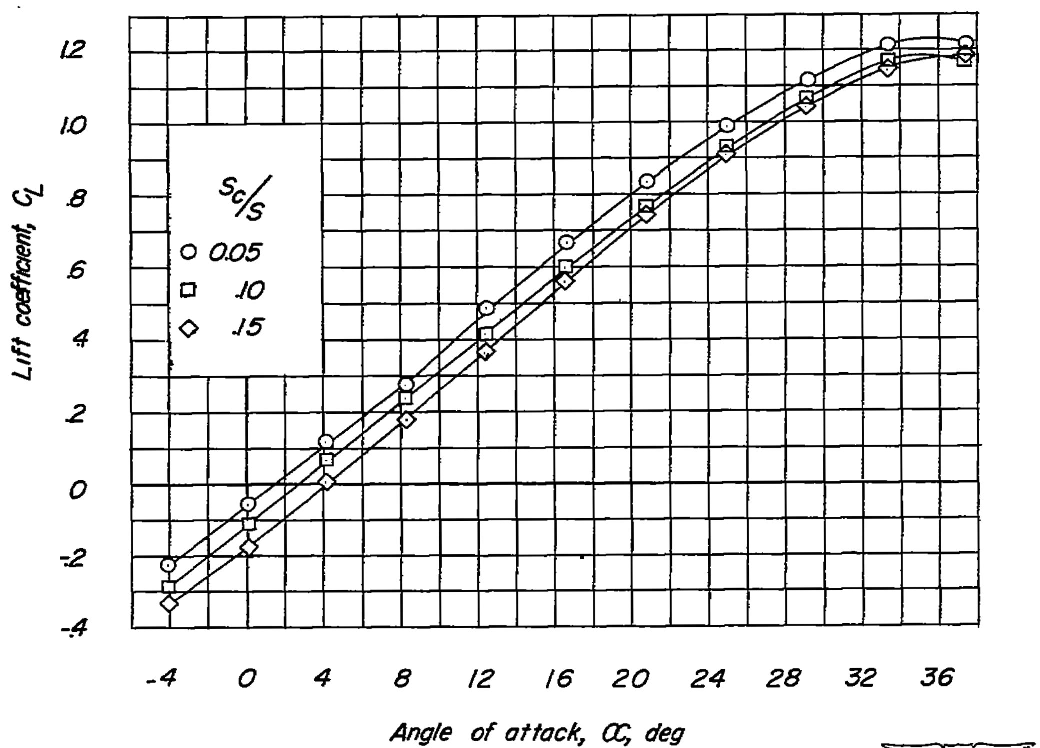


(b) Rear view.

Figure 3.- Concluded.

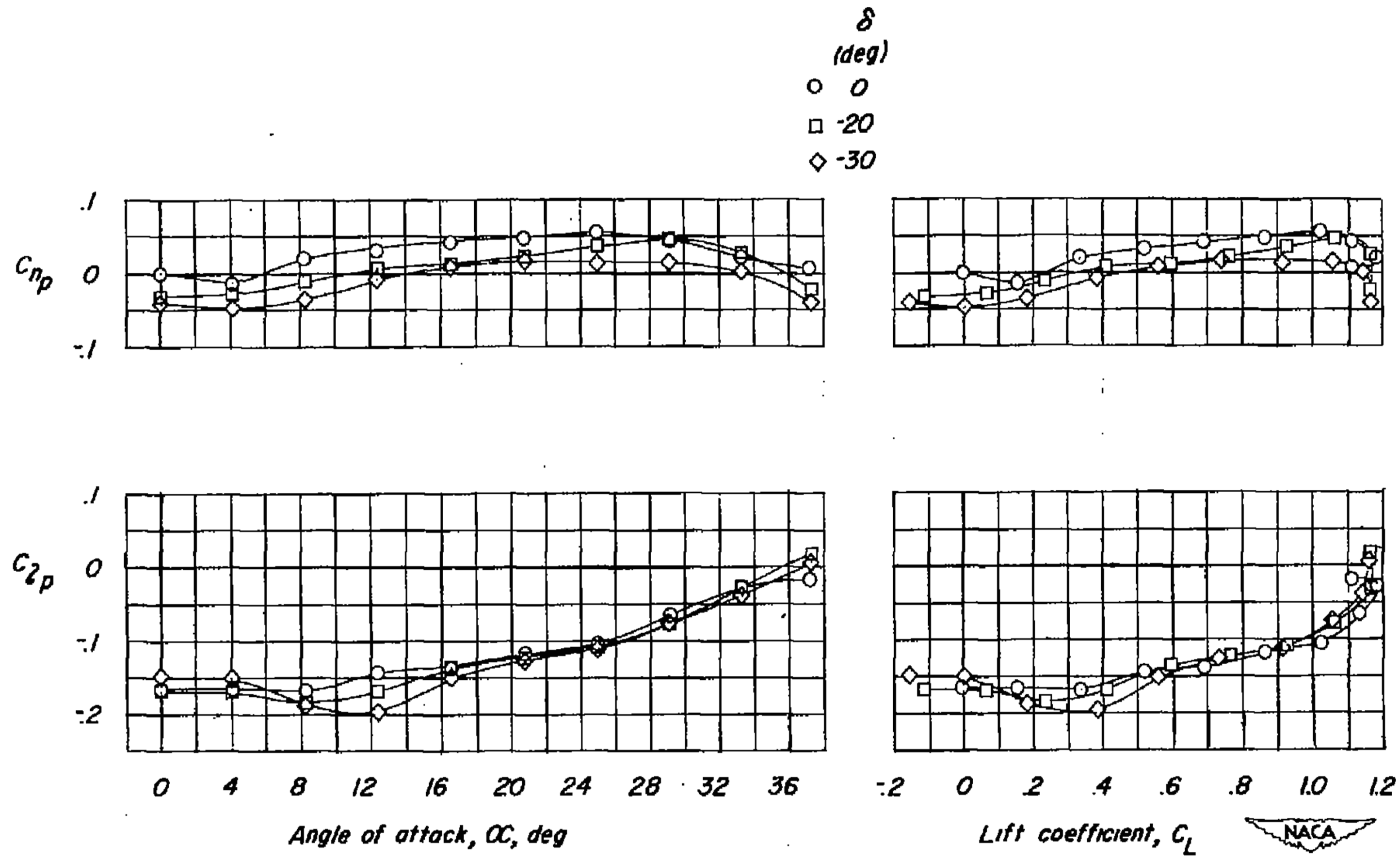


(a) C_L plotted against α. $\frac{S_c}{S} = 0.10$.



(b) C_L plotted against α. $\delta = -20^\circ$.

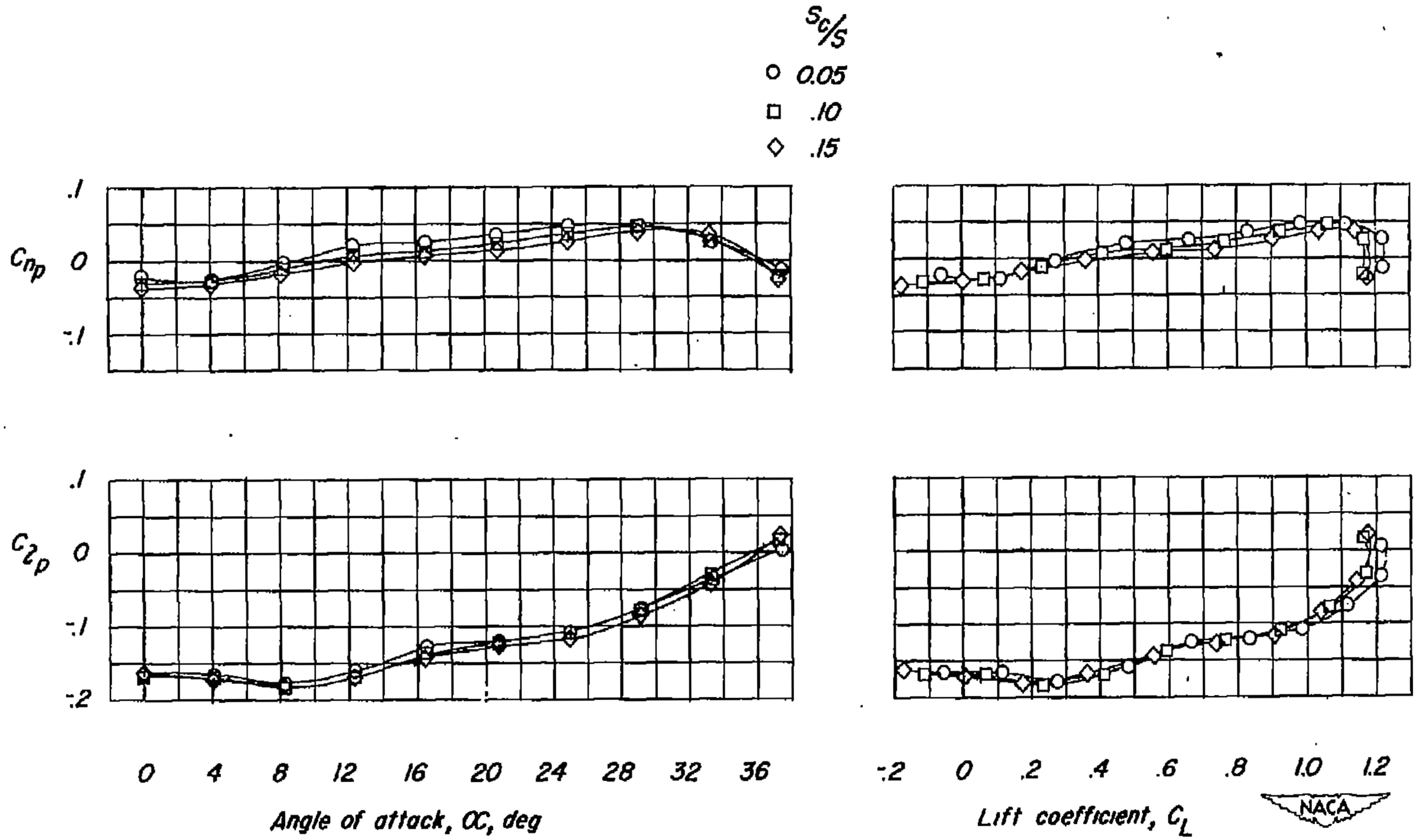
Figure 4.- Variation of lift coefficient with angle of attack for the various control deflections and control sizes investigated.



(a) C_{n_p} and C_{l_p} plotted against α.

(b) C_{n_p} and C_{l_p} plotted against C_L.

Figure 5.- Effect of control deflection on the variation of C_{n_p} and C_{l_p} with angle of attack and lift coefficient. $\frac{S_c}{S} = 0.10$.



(a) C_{n_p} and C_{l_p} plotted against α.

(b) C_{n_p} and C_{l_p} plotted against C_L.

Figure 6.- Effect of control size on the variation of C_{n_p} and C_{l_p} with angle of attack and lift coefficient. $\delta = -20^{\circ}$.